Dredging Research

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Worm gut fluids may yield key to assessing contaminant bioaccumulation potential in dredged materials (Part 1)

By Rod Millward, ERDC, Vicksburg, Environmental Laboratory, contractor support

Editor's Note: In the next two issues of *Dredging Research*, the progress of a LEDO-supported research project using gut fluids collected from large benthic worms to assess the bioavailable fraction of contaminants associated with dredged materials will be reported. Part 1 consists of some of the background to bioaccumulation and gut fluid extractions and introduces a research effort currently under way by members of the U.S. Army Corps of Engineers' Environmental Laboratory at ERDC, Vicksburg, Miss. Part 2 will present research results and discuss how they relate to current Corps guidelines for assessment of dredged materials.

Over evolutionary time, sediment-dwelling invertebrates have developed a complex cocktail of chemicals within their intestinal tract, enabling efficient and rapid extraction of food from indigestible materials, and solubilization into absorbable forms. The composition of this cocktail differs widely between different animal phyla, but generally includes digestive enzymes, amino acids, and powerful surfactants. These factors have enabled benthic organisms to extract nourishment from often nutrient-poor food sources, such as sediments.

However, one unwelcome consequence of this well-developed digestive system is that gut fluids can dissolve many sediment-associated environmental contaminants with a high efficiency. Studies have shown that specific amino acids in gut fluids are key to the mobilization of toxic metals from sediments, while powerful surfactants aid the solubilization of hydrophobic organic contaminants. Once dissolved, these contaminants are highly available for adsorption, possibly resulting in bioaccumulation, or potential toxicity. While contaminant bioaccumulation might not pose much of a hazard to the benthic organism, predation upon these benthic organisms can lead to significant biomagnification and consequently a significant potential risk to organisms higher up the food chain, eventually including humans. Therefore, assessment of bioaccumulation potential in benthic organisms can be essential when considering contamination exposure risk within the human population.

This potential for contaminant bioaccumulation in benthic animals is well documented and is addressed in the Corps' guidelines for dredged material evaluation (U.S. Environmental Protection Agency and U.S. Army Corps of Engineers 1991, 1998). Prior to disposal of dredged materials at a reference site, dredged material must be shown to pose no greater bioaccumulation hazard than do sediments representing the proposed disposal site. Therefore, a reliable method for assessing bioaccumulation is of paramount importance when assessing the risks posed by disposal of dredged material.

However, assessment of bioaccumulation potential for contaminated sediments is far from straightforward.

In this issue . . .

Only a limited proportion of the total sediment-associated contaminants is available for absorption into organisms, due to the activity of various sorption phases within sediments. Obviously, the most direct way to assess potential bioaccumulation is to perform a standard bioaccumulation assay. Typically, such assays will expose replicated groups of benthic organisms (often polychaete worms and/or clams) to the test sediment and reference sediment under controlled conditions for 28 days, and subsequently compare body burdens of each contaminant of concern. However, such tests are expensive and laborious, particularly in cases of multiple contaminants.

One alternative, available for nonpolar organic compounds, is to predict the contaminant bioaccumulation potential, using thermodynamic partitioning models. These models presume that organic contaminants approach equilibrium between the organic carbon in the sediment and the fatty reserves in the organism. Therefore, by knowing the total concentrations of contaminant, organic carbon content in the sediment, and the lipid in an organism, the concentration of contaminant in the tissues at equilibrium can be predicted. Currently this thermodynamically derived bioaccumulation potential (TBP) model is used as a screening tool to evaluate the potential for bioaccumulation in the dredged material and in the reference material. As such, it offers a cheap alternative to the full-fledged bioaccumulation tests. However, TBP is limited to nonpolar organic contaminants. Currently there are no screening tools for metals; hence, identification of elevated metal concentrations in dredged materials compared to the reference site necessitates the use of costly bioaccumulation studies.

It is clear that the current testing guidelines would benefit from a simple, inexpensive screening tool for assessing the bioaccumulation potential for metals, reducing the need for expensive and laborious bioaccumulation tests. Theoretically, the comparison of metals extracted from dredged and reference sediments using gut fluids may offer such a tool.

Figure 1. The marine worm Arenicola brasiliensis *from which gut fluids are often collected*

Using gut fluid to measure bioavailability

The concept of using gut fluid extraction to estimate contaminant bioavailability was first proposed in 1996 and has been developed largely by Dr. Donald Weston (U.C. Berkeley), Dr. Laurence Mayer (U. Maine), and colleagues. The theory is attractively simple. Often, the major source of contaminant uptake is via ingested material. Therefore, measurement of the proportion of contaminant removed by gut fluid should provide a good estimate of the bioavailability of contaminants to organisms, and might allow prediction of which sediments pose a bioaccumulation hazard and which do not. Should this predictive ability prove robust, extraction of contaminated sediments using invertebrate gut fluids might offer the Corps a screening tool for bioaccumulation potential of a wide range of contaminants in dredged materials.

The method is simple: large invertebrate worms (chiefly the polychaete *Arenicola brasiliensis,* Fig. 1) are collected from an uncontaminated coastal site and dissected carefully to remove gut fluids – typically 0.5 mL per worm. Gut fluids from this species are typically a dark brown color due to the high concentration of various dissolved organic compounds and appear 'soapy,' reflecting the high concentration of surfactants. Once collected, gut fluids can be frozen until required. Work is currently under way at the University of Maine to develop a synthetic gut fluid, both to alleviate the need to use wild animals for future tests and to reduce variability between gut-fluid samples. Extraction procedures involve placing approximately 1 g of wet sediment into a few milliliters of gut fluid, mixing well, and then leaving for 2 to 4 hr with constant agitation. The gut fluid can then be removed by centrifugation and decanting the supernatant, and analyzed for the contaminant of concern.

Can gut fluid extraction predict bioaccumulation?

In a recent study, Weston and Maruya (2002) showed that gut fluid extractions may help predict bioaccumulation potential in contaminated sediments. The authors collected 12 sediments from San Francisco Bay and performed standard chemical analyses, bioaccumulation tests, and gut fluid extractions using the marine bivalve *Macoma nasuta* (Fig. 2). Chemical analysis indicated that the sediments might pose a potential bioaccumulation hazard for a number of contaminants. However, the bioaccumulation trials revealed that only a small fraction of these contaminants were actually bioaccumulated in organisms, confirming a multitude of studies which indicate that prediction of bioaccumulation is problematic when based on contaminant concentration data alone.

However, gut fluid extractions proved to be a good predictor of bioaccumulation potential for most contaminants, with one notable exception. Gut fluid extractions showed high incidences of elevated Cr solubilization, although only in one case was Cr bioaccumulated in *Macoma*. This result was not at all surprising and is due to the extremely limited ability of organisms to assimilate solubilized Cr.

Figure 2. The marine bivalve Macoma nasuta, *commonly used in bioaccumulation studies*

When the Cr data were removed from the comparison, the ability of gut fluid solubilization to predict bioaccumulation became even more promising; elevated gut fluid extractions correctly predicted 71 percent of all occurrences of bioaccumulation. If further validated, this property could form the basis for a simple dredged material screening tool for metals to work alongside the current TBP.

Studies currently under way continue the approach of Weston and Maruya, exposing a range of metal-contaminated sediments to both gut fluid extraction and bioaccumulation tests using the polychaete worm *Neanthes arenaceodentata*.

References

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. (1991). "Evaluation of dredged material proposed for ocean disposal - Testing manual," EPA-503/8-91/001, Washington, DC. *http://www.wes.army.mil/el/dots/guidance.html*

_____ . (1998). "Evaluation of dredged material proposed for disposal in waters of the U.S. - Testing manual," EPA-823-B-004, Washington, DC. *http://www.wes.army.mil/el/dots/guidance.html*

Weston, D. P., and Maruya, K. A. (2002). "Predicting bioavailability and bioaccumulation using *in vitro* digestive fluid extraction," *Environ. Toxicol. Chem.* 21(5), 962-971.

Additional information is available from Rod Millward, *Roderic.N.Millward@erdc.usace.army.mil.*

. . . and it's free

A magazine that concentrates on dredging and port construction projects around the world - and publishes a free international directory of dredgers every year - is available for the asking.

That's *Dredging & Port Construction (DPC)*, which is the official magazine of the Central Dredging Association (CEDA) and of the Eastern Dredging Association (EADA). In addition, Larry Patella, executive director of the Western Dredging Association (WEDA) is on DPC's editorial board, and the journal has numerous WEDA subscribers throughout the USA and South America.

If you haven't seen it and would like a free sample copy, get in touch with editor Tony Slinn at: Dredging & Port Construction, DMG World Media, Queensway House, 2 Queensway, Redhill, Surrey RH1 1QS, UK - tel: from the U.S. 011-44-1-737-855-279; fax: +44-(0)1-737-855-470; E-mail: *dpc@uk.dmgworldmedia.com* or *tonyslinn@uk.dmgworldmedia.com*

Flexible pipeline increases ship channel safety for dustpan dredge operations during marsh creation (Part 1)

Part 1 of a two-part series to be concluded in Dredging Research, Vol 5, No. 4, Dec. 2002. Material provided by ERDC Vicksburg, New Orleans District, and Louisiana state agency personnel, Elke Briuer, APR, editor

Louisiana's coastline is changing dramatically as it loses more than 75 km^2 of marshes and coastal lands each year. Innovative methods for restoring such areas include placement of dredged material removed to maintain navigation for marsh construction and rehabilitation.

In the past, during maintenance work on the lower Mississippi River, cutterhead dredges with pipeline discharge were used to create marshes in the Head of Passes at a reasonable cost. However, cutterhead dredges have limited maneuverability and are a hazard to large ships navigating through the restricted channel. Marsh creation with cutterhead dredges was discontinued at the Head of Passes to maintain navigation safety in the channel, although they are still in such use in Southwest Pass between Head of Passes and the jettied channel. Hopper dredges now maintain the ship channel in the lower portions of the Mississippi River above Head of Passes because their mobility allows safe navigation. However, material removed by hopper dredges is not used to create marsh. In order to use material removed by a hopper dredge for marsh creation, sediments must be directly pumped out of the hopper as it is tied to a buoy or barge. Dredge maneuverability decreases when the vessel is tied to a barge, a safety concern, and direct pump-out increases the cost of hopper dredging as it takes more time, a negative economic impact. Furthermore, during periods of rapid shoaling, it is imperative that the hopper dredges maintain high production rates in order to keep the channel open to ship traffic. Maintaining high production is not possible with prohibitively time-consuming pump-out operations.

Dustpan dredges are used routinely on the lower Mississippi River above Head of Passes to maintain the navigation channel. Dustpans are hydraulic dredges that use a wide, flat dredge head assisted by water jets (see online animation, *http://www.wes.army.mil/el/dots/doer/tools.html*) to dredge the free-flowing, cohesionless sediments found in the Mississippi River. Most dustpan dredges are self-propelled, assisted by two bow anchors, and have sufficient mobility for required safe passage of traffic on the lower Mississippi. These dredges have high-volume, low-pressure pumps capable of pumping dredged material to distances of approximately 300 m (900 ft) through rigid pipelines, allowing placement of sediment in shallow portions of the river. This distance, however, is not sufficient to reach the marshes.

For marsh creation in the Head of Passes, the ideal dredge must

- operate efficiently and economically
- have sufficient maneuverability in and out of the restricted navigation channel to allow safe passage to other vessels
- be able to pump dredged material in excess of 300 m (900 ft) (often, distances of up to 3,000 m (10,000 ft) are required to place material in a marsh), and
- have a flexible pipeline that allows the dredge to quickly move into, out of, and across the channel.

As noted above, there is a strong desire to use sediments dredged for navigation beneficially for marsh creation in southern Louisiana; however, at Head of Passes, navigation safety, economics, and maintaining authorized channel depth are major considerations. A potential solution at this location is a dustpan dredge with a unique, flexible pipeline which gives the dredge the maneuverability that is lacking with the cutterhead dredges, and other modifications that would meet the requirements outlined above.

To verify this hypothesis, the U.S. Army Corps of Engineers' New Orleans District, with the State of Louisiana as the primary sponsor, proposed a demonstration in the lower portion of the Mississippi River, at the Head of Passes in June 2002. The work was collaborated by scientists and engineers of the Corps' research facility, ERDC, Vicksburg, Miss. The DOER program's focus on identifying and demonstrating emerging dredging and dredged material management technologies in cooperation with field offices provided an ideal fit for this demonstration project.

Dustpan demonstration

The contractor-owned dustpan dredge *Beachbuilder* was provided for the demonstration. The *Beachbuilder* is a nonself-propelled dustpan with a total pumping capacity of 10,000 hp, designed primarily for beach nourishment projects on the east coast. A tug connected to the stern of the *Beachbuilder* provided additional maneuverability for the dredge on this project.

Dredging operations were modified by using a two-wire/anchor lines positioning system ("upstream" forward port and starboard) instead of the usual six-wire/anchor lines (forward and aft). Minimizing the anchor lines allowed the dredge to maneuver in and out of the channel more easily. These anchors were placed outside the navigation channel template on the right and left descending bank sides, upstream of the dredge.

Additionally, the *Beachbuilder* was to discharge the dredged material through a flexible, floating hose connected to a "hard point," an anchored transition point from the floating hose to a submerged line in the river. This line was, in turn, connected to a pipeline that emerged from the water to become the shore pipeline on "dry" land into the marsh. The flexible, floating hose was approximately 430 m (1,420 ft) in length, allowing the dredge to work the entire width of the navigation channel. The shore pipeline terminated in a simple pipe cutoff. Sections were added as needed. The maximum pipeline length of the entire hydraulic circuit was 1,963 m (6,440 ft) (Fig. 1)

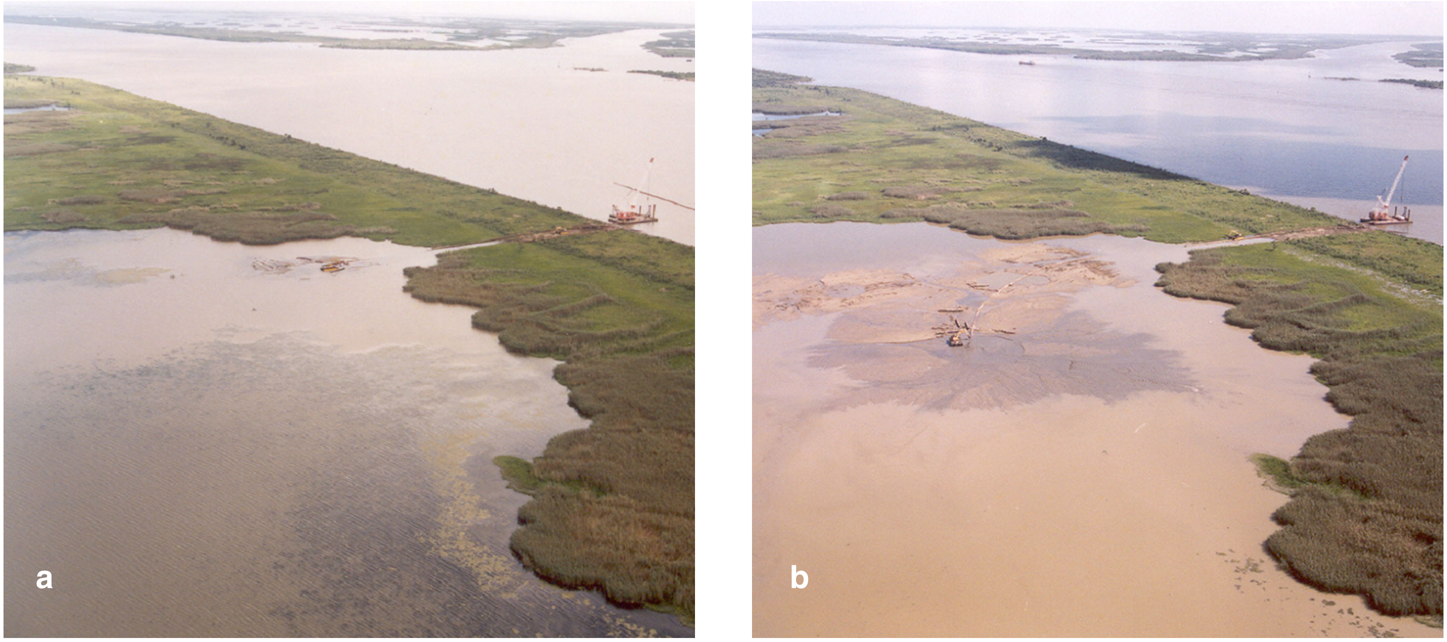
After mobilization was complete, vessel maneuvering trials were conducted before any pumping occurred to verify the *Beachbuilder's* ability to safely maneuver in, and completely out, of the channel to accommodate passing vessels. A registered Mississippi River Bar Pilot was aboard the dredge for these trials (as well as during dredging operations throughout the demonstration) to direct *Beachbuilder* maneuvers during heavy river traffic. Whenever a deeper draft vessel passed outboard the

Figure 1. Dredge Beachbuilder *with tug astern and its floating, flexible hose configuration restoring marshland at Head of Passes. The beginning of the shore pipeline is located in the upper left-hand side of the picture by the barge-mounted crane*

Figure 2. Deep draft vessel passing Beachbuilder

Beachbuilder (outboard is on the left descending bank side), the cross-channel anchor wire was dropped to allow the vessel to pass over. Figure 2 shows a large vessel navigating past the *Beachbuilder* and the floating hose. This figure also illustrates the importance of sufficient maneuverability for this type of operation. Although vessels were not supposed to pass between the *Beachbuilder* and the hard point because of the floating hose, a shrimp boat managed to do so, fortunately without significant damage to the shrimper or the discharge hose.

The dredging demonstration took place June 5-13, 2002, during some of the highest river stages experienced on the lower Mississippi in recent years, and after the dredge maneuverability was deemed sufficient by the Corps', the contractor's, and the Bar Pilot's representatives.



Figures 3. View of marsh (a) shortly after initiating placement and (b) after dredged material placement was completed

The higher river stages provided the opportunity to test the dredge's ability to maintain position, advance, and maneuver while experiencing maximum current-induced forces on the dredge and discharge line. The maximum measured current during the demonstration period was 2 m/s (7 ft/s). Operational data collected during the demonstration included

- production meter and positioning data
- leverman logs, before and after surveys of the channel and marsh
- geotechnical samples

Once analyzed, the data and the results, along with "lessons learned" from the demonstration, will be available online at *www.wes.army.mil/el/dots/doer* as DOER technical notes or reports under the Innovative Technology subject area.

Approximately 190,000 cu m (250,000 cu yd) were placed in the marshland (Fig. 3). Marsh construction using the dustpan resulted in some "higher" above water level dredged material spots in the placement area. The New Orleans District, in cooperation with State and Federal natural resources agencies, has determined that the initial height of the dredged material cannot exceed a vertical placement height of 1.07 m (3.5 ft) Mean Lower Gulf (MLG). Grading was started less than 1 week after dredging was completed, but by that time more than 20 least tern nests (Fig. 4) were found at various locations in the placement area. Corps investigators consulted with the State of Louisiana and a decision to stop grading of the dredged material was issued in order to preclude any damage to the least terns' nests.

Results from this demonstration are expected to assist the Corps in determining the feasibility of using this dredged material placement method in future marshland restoration projects and will be addressed in a followup article in *Dredging Research*.

Figure 4. Least tern nest on newly placed dredged material for marshland restoration

Additional information is available by contacting Jim Clausner, *James.E.Clausner@erdc.usace.army.mil*, focus area manager for DOER Innovative Technologies.

Environmental stability of chemicals in sediments to be topic of upcoming workshop

A 3-day workshop will be held in San Diego April 8-10, 2003, on

- biochemical and physical factors that modify the stability, mobility, and/or bioavailability of inorganic and organic contaminants in aquatic sediments;
- fate, effects, and risks of sediment-bound contaminants;
- agreement on general, yet pragmatic, guidance for the assessment and management of contaminated sediments that may pose an unacceptable human health and/or environmental risk.

Anyone working with or interested in the various aspects of managing contaminated sediments is invited to attend. The meeting is open to the public. Workshop arrangements are under way, organized by a steering committee with members from the U.S. Army Corps of Engineers, EPA, Navy, USGS, NOAA, DuPont SMWG, and HSRC S/SW (LSU). Results will be posted online at *http://www.sediments.org*.

More information is available from Dr. Robert M. Engler, chair, E-mail *robert.m.engler@erdc.usace.army.mil*.

Dredging Calendar

2002

October 15-16 - WEDA Gulf Chapter Meeting will be held at Jefferson Orleans South, Metairie, LA. **POC:** Charlie Settoon at 504-889-0182. Contact LandMark Hotel in Metairie for reservations.

October 16-18 - 5th International Symposium on Sediment Quality Assessment, 2002. Hotel Allegro, Chicago, IL, USA. **POC:** *http://www.aehms.org*

October 22-24 - CEDA Dredging Days-Dredging Without Boundaries; Casablanca, Morocco. **POC:** Anna Csiti, CEDA Secretariat, Delft, The Netherlands, Tel: 011-31 15-2783145 or E-mail *ceda@dredging.org*.

November 16-22 - SETAC (Society of Environmental Toxicology and Chemistry) North America 23rd Annual Meeting, Salt Lake City, UT. *Achieving Global Environmental Quality: Integrating Science & Management*. **POC:** *www.setac.org/meet.html*

2003

January 12-16 - TRB 82nd Annual Meeting, 2003,The Marriot Wardman Park, Omni Shoreham, and Hilton Washington hotels in Washington, DC, host more than 450 formal sessions and 300+ committee meetings. More than 8,500 transportation professionals from the United States and abroad are expected to attend. More information can be found at: *http://www4.nationalacademies.org/trb/annual.nsf*

April 8-10 - Environmental Stability of Chemicals in Sediments Workshop, San Diego. Results will be posted online at *http://www.sediments.org*. **POC:** Dr. Robert M. Engler, E-mail *robert.m.engler@erdc.usace.army.mil.*

April 13-16 - Inaugural National Conference on Coastal and Estuarine Habitat Restoration, Baltimore, MD, Hyatt Regency Inner Harbor. The conference is the first nation-wide forum focused solely on the goals and practices of coastal and estuarine habitat restoration. **POC:** Rick Bates, Development Director at Restore America's Estuaries, at (703) 524-0248, E-mail *rickbates@estuaries.org*

May 26-28 - 2nd International Symposium on Contaminated Sediments. Loews Le Concorde Hotel, Quebec City, Canada. Sponsors: ASTM, CGS, CSCE, SRA-SETAC. **POC** and information can be found at: *http://www.scs2003.ggl.ulaval.ca/SCS2003_English.pdf*

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Articles from non-ERDC authors are solicited for publication, especially if the work described is tied to the use of ERDC-generated research results. Research articles that complement ERDC research or cover wide field applications are also accepted for consideration. Manuscripts should use a nontechnical writing style and should include suggestions for visuals and an author point of contact. Point of contact is Elke Briuer, APR, at ***Elke.Briuer@ erdc.usace.army.mil*****.**

Dredging Research

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the U.S. Army Engineer Research and Development Center. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program and includes information about various dredging research areas. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Contributions are solicited from all sources and will be considered for publication. Editor is Elke Briuer, APR, *Elke.Briuer@erdc.usace.army.mil*. Mail correspondence to the Environmental Laboratory, ATTN: DOTS, Dredging Research, U.S. Army Engineer Research and Development Center, Waterways Experiment Station (CEERD-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-2349. Internet address: *www.wes.army.mil/el/dots/drieb.html*.

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